

# Floristic diversity, regeneration status, and vegetation structure of woodlands in Metema Area, Amhara National Regional State, North-western Ethiopia

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Received: 2011-06-01

Accepted: 2011-10-19

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**Abstract:** We studied woodland vegetation in broad-leaved deciduous woodlands of Metema in northwestern Amhara regional state, Ethiopia. Our objective was to describe plant species composition, diversity, regeneration status, and population structure by a selective approach with a systematic sampling design. A total of 74 quadrats (each for 25 m × 25 m, spaced at intervals of 150–200 m) were sampled along established transect lines following the homogeneity of the vegetation. Vegetation data including cover-abundance, height, diameter at breast height (DBH), and numbers of seedlings and saplings of woody species were analyzed using Excel spreadsheet, Shannon Weiner diversity index, and PAST version 1.62. A total of 87 vascular plant species of 74 genera and 36 families were recorded. The dominant family was Fabaceae represented by 16 (18.39 %) species of 13 genera. Shannon Weiner diversity and evenness were 3.67 and 0.82, respectively, which showed that the area was endowed with rich floral diversity evenly distributed. The vegetation structure, as quantified by cumulative diameter class frequency distribution, plotted as an interrupted inverted-J-shape pattern with a sharp decrease in the 2nd diameter class. This indicated poor vegetation structure. The diameter classes frequency distributions of selected species plotted in four general patterns i.e., interrupted Inverted-J-shape, J-shape,

Bell-shape and Irregular-shape. In conclusion, although the area showed high floral diversity and evenness, woody species including *Sterculia setigera*, *Boswellia papyrifera*, and *Pterocarpus lucens* showed lowest recruitment of seedlings and saplings.

**Keywords:** equitability; diversity; dryland; Metema Woodland; population structure; regeneration

## Introduction

There is limited information on location, extent, and volume of the standing stock, and annual growth rates of the forest resources in Ethiopia. Forests and woodlands have been declining both in size (due to deforestation) and quality (due to degradation) (EFAP 1994). Absence of protective forest policy is enabling rapid deforestation, especially in the arid and semiarid regions of Ethiopia.

Four broad vegetation types can be distinguished in the arid and semiarid regions of Ethiopia (Friis 1992): broad-leaved deciduous woodland, small-leaved deciduous woodland, lowland dry forest, and lowland semi-desert and desert vegetation. In recent years, increasing human pressure in the drylands combined with global climate change is further intensifying problems in dry regions that are becoming increasingly arid and vulnerable, and less suitable for habitation in the arid and semiarid regions of Ethiopia (Aki-maliev 2005).

Metema area is one such dryland part of Ethiopia, located in northwestern Amhara Regional State. Like other dryland parts of the country, land degradation is rife in Metema area because of over exploitation of woodlands and farming of fragile lands. Burning and overgrazing have resulted in the clearing of woodlands. This has accelerated soil erosion and destroyed the soil and floristic diversity of the area (Sisay 2006). Resulting problems in the region have been reported by Abeje et al. (2005), Mulugeta et al. (2007), Sisay (2006) and Tatek (2008). However, most of these studies were focused on only woody species with emphasis on the

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Responsible editor: Zhu Hong

population structure and soil seed bank. Managers and administrators lack baseline information on general plant diversity, composition, population structure, and other ecological perspectives. Our research was carried out to fill this gap by providing data on the diversity of plant species, population structure, and the regeneration status of woody plant species.

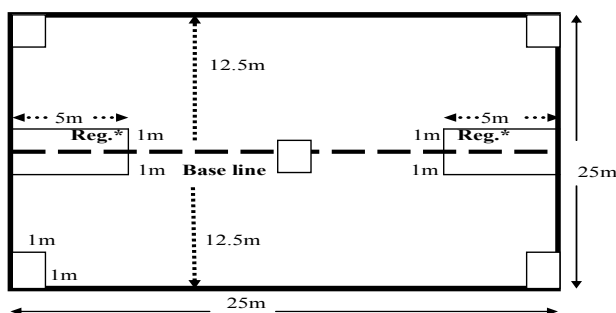
## Materials and methods

### Description of the study area

Our study area was in Metema district, located at 36°17' E (204893 UTM) and 12°39' N (139996 UTM) in North Gondar, about 975 km northwest of Addis Ababa. It lies within an altitudinal range of 550–1608 m a.s.l. The total area of the district is about  $4.40 \times 10^5$  hectares. Annual rainfall at Metema ranges from 514.4 to 1,128 mm with a mean annual rainfall of 924.2 mm (National Meteorological Agency of Ethiopia 2009). Mean monthly minimum and mean monthly maximum temperature of Metema district are 19.31°C and 35.65°C, respectively. Mean annual temperature is 32.98°C.

### Methods of data collection

We systematically sampled quadrats of  $25 \text{ m} \times 25 \text{ m}$  ( $625 \text{ m}^2$ ) at intervals of 150–200 m, following the homogeneity of the vegetation. For tree and shrub assessment, the  $625 \text{ m}^2$  quadrats were sampled. For seedling and sapling inventory, two subquadrats of  $2 \text{ m} \times 5 \text{ m}$  were sampled at the beginning and the end of the base line on opposite sides of the main quadrat. For herbaceous species and soil sampling, we sampled five  $1 \text{ m} \times 1 \text{ m}$  sub-quadrats within each  $625 \text{ m}^2$  quadrat with four subquadrats at the corner and one at the center (Fig. 1).



**Fig. 1 Sampling design.** Reg.\* is seedling and sapling regeneration sub-quadrats.

All plant species in all quadrats were recorded. The cover abundance of all vascular plants in each quadrat was estimated using the visual eye judgment. For all trees and shrubs we measured Height and diameter at breast height (DBH). For regeneration assessment, we counted seedling and sapling numbers by species in the two  $2 \text{ m} \times 5 \text{ m}$  subquadrats. In all quadrats, additional trees and shrubs outside the quadrat boundaries but within 10–15

m were collected and noted as present. Herbaceous species encountered outside the subquadrats were collected and noted as present. Plant specimens were brought to the National Herbarium of Addis Ababa University for identification. Specimens were dried and identified with reference to authenticated specimens (Edwards et al. 1995, 1997; Hedberg and Edwards 1989).

### Species composition and diversity

Species richness (number of species) was determined by summing up the number of species identified (Whittaker 1972). Shannon-Weiner diversity index was used to quantify floristic diversity and evenness. For analysis, the cover-abundance value of each encountered species was used.

### Population structure and importance value index (IVI)

To analyze the population structure of the vegetation, height and diameter frequency distribution of all tree and shrub species was calculated by measuring height and DBH for each species in all quadrats. To describe population structure, individuals of recorded species were grouped into diameter classes at increments of 4 cm and height classes at increments of 2 m. Structure was depicted using frequency histograms for both diameter and height class distributions following Peters (1996). The resulting frequency histograms were then interpreted as an indication of regeneration status. Only tree species with higher Importance Value Index (IVI) were selected for analyses of population structure. IVI enables comparison of the ecological significance of species in a given forest type. IVI was calculated following as:

$$IVI = R_D + R_{Dom} + R_F \quad (1)$$

$$R_D = (N_i \div T_n) \times 100 \quad (2)$$

$$R_F = (F_s \div T_s) \times 100 \quad (3)$$

$$R_{Dom} = (A_s \div T_c) \times 100 \quad (4)$$

where,  $IVI$  is the importance value index;  $R_D$  is relative density;  $R_{Dom}$  is relative dominance;  $R_F$  is relative frequency.  $N_i$  is number of individuals of a species in the sample;  $T_n$  is total number of individuals of all species in the sample.  $F_s$  is frequency of a species in the sample;  $T_s$  is total frequency of all species in the sample.  $A_s$  is area occupied by a species in the sample ( $\text{m}^2$ );  $T_c$  is total cover of all species in the sample ( $\text{m}^2$ ).

### Regeneration status

The regeneration status of woody species was summarized based on the total count of seedlings and saplings of each species across all quadrats.

## Results

### Floristic plant species composition

In total, 87 vascular plant species were identified from 74 quadrats. These species represented 36 families and 74 genera. The five dominant families were Fabaceae, representing 16 (18%) species in 13 genera, Poaceae 9 species (10%) in eight genera, Combretaceae 7 species (8%) species in three genera, Acanthaceae 5 (6%) species in five genera and Asteraceae 5 (6%) species in five genera (Appendix 1). By growth habit, 42 (48%) species were herbs, 3 (4%) climbers, 3 (4%) shrubs, 13 (15%) shrub or trees and 26 (30%) trees.

### Density, DBH, and height of woody species

Overall diversity was 3.67, relatively high diversity. The 87 species in the area were distributed evenly with the Shannon evenness value of 0.82 and low dominance (0.04). A total of 1,743 woody plants (376.86 plants per ha) were recorded in 74 quadrats (Table 1). The six woody species occurring at highest density were *Sterculea setigera*, *Boswellia papyrifera*, *Anogeissus leiocarpa*, *Lannea fruticosa*, *Dichrostachys cinerea*, and *Pterocarpus lucens*.

The cumulative diameter class distribution pattern was an interrupted reverse-J-shape, showing a decline in density of diameter class 2. However, the density of woody plants generally declined with increasing diameter classes. The 56% of the total tree density was distributed between the first and fourth diameter classes, whereas, 30% and 14% of tree density was found to be both in the middle diameter classes (between fifth and 8th) and the higher diameter classes (between 9<sup>th</sup> and 12<sup>th</sup>), respectively (Fig. 2).

The density distribution of trees by height class showed a pattern similar to that seen for diameter classes although there were a sharp decline in density of classes 2, 3, 4 and 5. Density generally declined with increase in height class (Fig. 3).

### Basal area and importance value index (IVI)

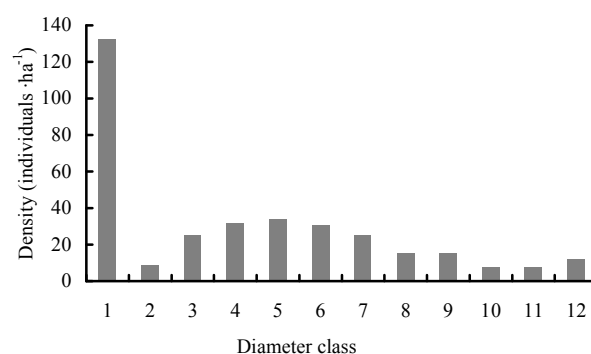
The basal area of all woody species was 42.54 m<sup>2</sup> per hectare. The species with the largest basal area were *Sterculea setigera* with the basal area contribution of 30.53%, *Boswellia papyrifera* (19.08%), *Anogeissus leiocarpa* (16.13%), *Pterocarpus lucens* (8.9%), *Lannea fruticosa* (7.03%), *Combretum collinum* (2.6%) and *Terminalia laxiflora* shared 2.48% of the total basal area. The remaining species contributed 13.25 % of total basal area (Table 1).

The 9 most important woody species with the highest IVIs were, in decreasing order, *Sterculea setigera* (44.46%), *Boswellia papyrifera* (40.28%), *Anogeissus leiocarpa* (23.86%), *Lannea fruticosa* (23.17%), *Pterocarpus lucens* (19.55%), *Combretum collinum* (10.58%), *Dichrostachys cinerea* (10.39), *Stereospermum kunthianum* (9.13%), and *Cobretum adenogonium*

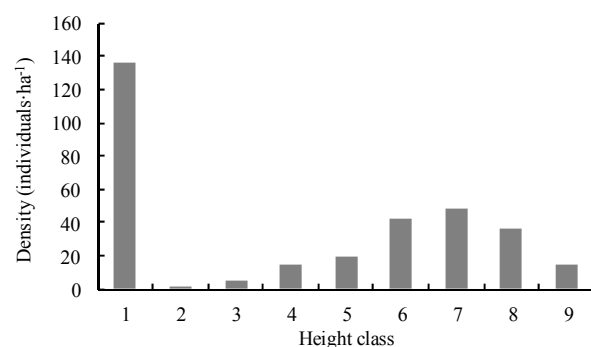
(8.64%). These contributed over 63% of the total IVI (Table 1).

### Population structure of woody species

The population structure of selected species followed four general diameter class distribution patterns. The first pattern was an interrupted Inverted-J-shape, which showed that the species frequency was highest in the lower diameter classes and decreased gradually towards the higher classes. The second pattern was a J-shape, which showed that the number of individuals was low in the lower diameter classes and increased towards the higher diameter classes. The third pattern was Bell-shape, which showed that the number of individuals were high in the middle classes, and decreased towards the lower and higher diameter classes.



**Fig. 2 Cumulative frequency distribution by diameter class of woody species.** DBH class: (1 represents 0–4 cm; 2 represents 4–8 cm; 3 represents 8–12 cm; 4 represents 12–16 cm; 5 represents 16–20 cm; 6 represents 20–24 cm; 7 represents 24–28 cm; 8 represents 28–32 cm; 9 represents 32–36 cm; 10 represents 36–40 cm; 11 represents 40–44 cm; and 12 represents > 44 cm).



**Fig. 3 Cumulative frequency distribution by height class of woody species.** Height class: (1 represents 0–2 m at height; 2 represents 2–4 m; 3 represents 4–6 m; 4 represents 6–8 m; 5 represents 8–10 m; 6 represents 10–12 m; 7 represents 12–14 m; 8 represents 14–16 m and 9 represents > 16 m).

The forth pattern was Irregular-shape, which showed an absence of plants in the second and third diameter classes. These patterns were illustrated by the six dominant species selected based on their importance value indices. Accordingly, *Anogeissus leiocarpa*, *Combretum collinum* and *Lannea fruticosa* followed an interrupted Inverted-J-shape pattern (Fig. 4(b), (c) and (e)). *Sterculea setigera* (Fig. 4 (a)) followed a J-shape pattern,

while *Boswellia papyrifera* and *Pterocarpus lucens* (Fig. 4(d) and (f)) followed Bell-shape and Irregular-shape patterns, respectively.

**Table 1.** Importance value indices for woody species

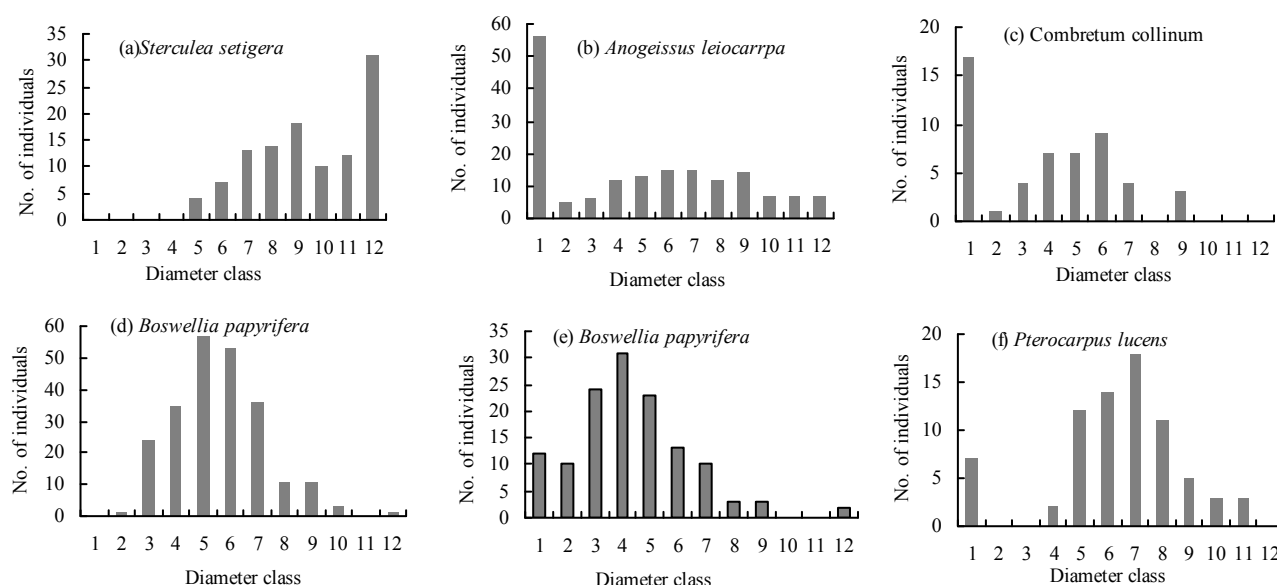
Species	Density (individuals·ha <sup>-1</sup> )	Relative density (%)	Relative frequency (%)	Relative basal area (%)	IVI (%)	IVI rank
<i>Acacia polyacantha</i>	8.22	2.18	2.41	0.15	4.74	19
<i>Acacia seyal</i>	6.05	1.61	1.77	0.60	2.53	24
<i>Acacia sieberiana</i>	3.68	0.98	1.27	0.49	2.73	23
<i>Albizia lophantha</i>	4.76	1.26	1.77	1.60	4.63	20
<i>Albizia melanoxylon</i>	0.43	0.11	0.25	0.33	0.69	33
<b><i>Anogeissus leiocarpa</i></b>	38.49	10.21	6.71	16.13	23.86	3
<i>Balanites aegyptiaca</i>	2.16	0.57	1.14	0.16	1.87	28
<i>Boscia mossambicensis</i>	0.43	0.11	0.25	0.00	0.36	37
<b><i>Boswellia papyrifera</i></b>	52.76	14	7.22	19.08	40.28	2
<i>Boswellia pirottae</i>	2.16	0.57	0.76	1.07	2.40	25
<i>Bridelia micrantha</i>	0.86	0.23	0.51	0.00	0.74	32
<i>Calotropis procera</i>	0.65	0.17	0.25	0.00	0.42	36
<b><i>Combretum adenogonium</i></b>	9.51	2.52	4.81	1.31	8.64	9
<b><i>Combretum collinum</i></b>	13.41	3.56	4.43	2.60	10.58	6
<i>Combretum hartmannianum</i>	0.43	0.11	0.25	0.07	0.43	35
<i>Combretum molle</i>	9.30	2.47	2.53	0.60	5.59	17
<b><i>Combretum</i> sp.</b>	8.43	2.24	3.92	1.45	7.60	10
<i>Dalbergia melanoxylon</i>	12.76	3.38	3.67	0.39	7.44	11
<b><i>Dichrostachys cinerea</i></b>	22.27	5.91	4.3	0.19	10.39	7
<i>Diospyros abyssinica</i>	1.08	0.29	0.38	1.64	2.31	26
<i>Ficus sycomorus</i>	1.30	0.34	0.76	0.00	1.10	31
<i>Ficus thonningii</i>	1.08	0.29	0.63	0.66	1.58	29
<i>Flueggea virosa</i>	14.27	3.79	2.41	0.00	6.19	16
<i>Gardenia ternifolia</i>	6.49	1.72	1.9	0.00	3.62	22
<i>Grewia bicolor</i>	1.30	0.34	0.76	0.16	1.26	30
<b><i>Lannea fruticosa</i></b>	29.84	7.92	8.23	7.03	23.17	4
<i>Lonchocarpus laxiflorus</i>	0.65	0.17	0.25	0.06	0.48	34
<i>Maytenus senegalensis</i>	0.22	0.06	0.13	0.00	0.19	39
<i>Maytenus undata</i>	12.97	3.44	3.29	0.54	7.27	12
<i>Ochna leucophloeos</i>	12.11	3.21	3.04	0.07	6.32	15
<i>Piliostigma thonningii</i>	0.22	0.06	0.13	0.10	0.29	38
<b><i>Pterocarpus lucens</i></b>	17.73	4.7	5.95	8.90	19.55	5
<b><i>Sterculea setigera</i></b>	27.24	7.23	6.71	30.53	44.46	1
<b><i>Stereospermum kunthianum</i></b>	15.78	4.19	4.68	0.27	9.13	8
<i>Strychnos innocua</i>	13.19	3.5	2	0.92	6.42	14
<i>Tamarindus indica</i>	0.22	0.06	0.13	0.00	0.19	39
<i>Terminalia laxiflora</i>	6.27	1.66	3.04	2.48	7.18	13
<i>Ximenia americana</i>	6.27	1.66	2.66	0.18	4.50	21
<i>Ziziphus abyssinica</i>	8.65	2.29	2.91	0.16	5.36	18
<i>Ziziphus spina-christi</i>	3.24	0.86	1.14	0.06	2.06	27
Total	376.86	100	100	100.00	300.00	-

**Notes:** First ten IVI ranked species are labeled in bold.

#### Regeneration status

Totals of 555 seedlings (120 individuals·ha<sup>-1</sup>) of 25 species were counted in all quadrats, while 85 saplings (14 individuals·ha<sup>-1</sup>) of 18 species were recorded. Accordingly, tree species

with the largest contribution to the seedling counts in descending order were *Flueggea virosa*, *Ochna leucophloeos*, *Anogeissus leiocarpa*, *Maytenus undata*, and *Dalbergia melanoxylon*. *Dichrostachys cinerea*, *Stereospermum kunthianum*, *Strychnos innocua* and *Dalbergia melanoxylon* showed the highest seedling counts of the shrub/ tree species (Table 2).



**Fig. 4** Diameter class frequency distribution of selected tree species. DBH class: (1 represents 0–4 cm of diameter; 2 represents 4–8 cm; 3 represents 8–12 cm; 4 represents 12–16 cm; 5 represents 16–20 cm; 6 represents 20–24 cm; 7 represents 24–28 cm; 8 represents 28–32 cm; 9 represents 32–36 cm; 10 represents 36–40 cm; 11 represents 40–44 cm; and 12 represents > 44 cm).

**Table 2.** Regeneration status of woody species

Species	Number of saplings	Number of seedlings	Habit
<i>Dichrostachys cinerea</i>	24	87	Shrub/tree
<i>Flueggea virosa</i>	0	64	Tree
<i>Stereospermum kunthianum</i>	6	52	Shrub/tree
<i>Anogeissus leiocarpa</i>	8	48	Tree
<i>Ochna leucophloeos</i>	0	53	Tree
<i>Maytenus undata</i>	4	39	Tree
<i>Strychnos innocua</i>	3	33	Shrub/tree
<i>Acacia polyacantha</i>	8	25	Shrub/tree
<i>Dalbergia melanoxylon</i>	7	22	Tree
<i>Ziziphus abyssinica</i>	1	26	Shrub/tree
<i>Gardenia ternifolia</i>	0	27	Shrub/tree
<i>Combretum collinum</i>	0	17	Shrub/tree
<i>Combretum molle</i>	1	14	Tree
<i>Acacia seyal</i>	4	10	Tree
<i>Lannea fruticosa</i>	2	8	Tree
<i>Ziziphus spina-christi</i>	3	7	Tree
<i>Acacia sieberiana</i>	0	7	Shrub/tree
<i>Pterocarpus lucens</i>	3	3	Tree
<i>Albizia lophantha</i>	0	6	Tree
<i>Balanites aegyptiaca</i>	6	0	Tree
<i>Ximenia americana</i>	0	2	Shrub/tree
<i>Calotropis procera</i>	2	0	Shrub
<i>Combretum hartmannianum</i>	0	1	Tree
<i>Lonchocarpus laxiflorus</i>	0	1	Tree
<i>Sterculea setigera</i>	1	0	Tree
<i>Grewia bicolor</i>	0	1	Tree
<i>Ficus thonningii</i>	0	1	Tree/shrub
<i>Cobretum adenogonium</i>	1	0	Tree
<i>Boscia mossambicensis</i>	0	1	Shrub/tree
<i>Bridelia micrantha</i>	1	0	Shrub/tree
Total	85	555	-

## Discussion

### Floristic composition

Floristic composition of vegetation can be described as indices for species richness, abundance, dominance, and frequency (Lamprecht 1989). In this study, a total of 87 species, including climbers, herbs, shrubs, shrub or tree, and tree, were recorded. Two tree species, *Smithia abyssinica* and *Boswellia pirottae*, are endemic to Ethiopia and *Boswellia pirottae* is listed as a threatened endemic plant species of Ethiopia. Overall diversity and evenness were 3.67 and 0.82, respectively. According to Kent and Coker (1992), the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5. In our study area, however, there is high diversity and evenness showing more or less even representation of individuals of all species in the sampled quadrats.

### Population structure

Species-abundance measures not only the relative richness but also evenness and diversity of species (Barnes et al. 1998). We recorded a total of 376.86 woody plants per ha from all quadrats. *Sterculea setigera*, *Boswellia papyrifera*, *Anogeissus leiocarpa*, *Lannea fruticosa*, *Dichrostachys cinerea*, and *Pterocarpus lucens* were the most abundant species while species like *Albizia melanoxylon*, *Combretum hartmannianum*, *Boscia mossambicensis*, *Piliostigma thonningii*, *Tamarindus indica*, and *Maytenus senegalensis* were poorly represented. Dominant species were few

while many species were very rare or of low abundance. This result reflects either adverse environmental conditions or random distribution of available resource in the woodland (Miranda et al. 2002, cited in Feyera et al. 2007). We suggest that woody plants were distributed in an uneven manner due to inability of individuals to cope up harsh environmental conditions (e.g. high temperature, low rainfall regime), human disturbance, livestock trampling and grazing, and other biotic and abiotic factors. The natural regeneration and dispersal patterns of species might also explain this uneven distribution of species (Elias and Dias 2009; Elias et al. 2011).

Species with highest dominance indices could be considered the most important species in the study vegetation. In most cases, shrubs could be the dominant species if we only consider density as a measure of overall dominance (Adefires 2006 1992; Simon et al. 2004). In our study, basal area analysis across individual species revealed that very few species had high dominance. *Sterculea setigera* was the leading dominant and other dominant species in terms of basal area were *Boswellia papyrifera*, *Anogeissus leiocarpa*, *Pterocarpus lucens*, *Lannea fruticosa*, *Combretum collinum*, and *Terminalia laxiflora*. This implies that these seven species are the most ecologically important woody species at Metema.

Species relative frequency reflects the pattern of distribution and gives an approximate indication of the heterogeneity of a stand (Haileab et al. 2006; Lamprecht 1989). In this study, it can be concluded as there were fairly few species in most of the quadrats. These species might have a wide range of seed dispersal mechanisms by wind, livestock, wild animal, or birds. According to Lamprecht (1989), species with the same IVI have the same or at least similar population structure. In contrast to this idea, almost all species in this study showed variation in terms of their IVI, showing different ecological importance of each species in the woodland.

Information on population structure of a tree species indicates the history of past disturbance of this species and its environment, which can be used to forecast the future trend of the population of particular species (Demel 1997; Tamrat 1994). In this study, the diameter class frequency distribution of selected species had four different patterns i.e. interrupted J-shape, Bell-shape, Irregular-shape and J-shape. According to previous studies (Alemayehu 2002; Alemnew 2001; Getachew et al. 2002, Mekuria et al. 1999; Silvertown 1982; Silvertown and Doust 1993), a reverse J-shape distribution pattern of species was considered as an indication of stable population status or good regeneration status. In this study, the cumulative diameter class distribution of species showed a nearly reverse J-shape with a sharp decline in density of the 2<sup>nd</sup> diameter class, reflecting the hampered regeneration profiles in the area. This tells us that there was a selective removal of small diameter class individuals either by local dwellers for some purpose (e.g. for fencing and fuelwood), or by livestock (trampling or browsing), or may be other biotic factors such as termite attack. Similarly, *Anogeissus leiocarpa*, *Combretum collinum*, and *Lannea fruticosa* were depicted in an interrupted reverse-J-shape. *Anogeissus leiocarpa* and *Combretum collinum* showed a sharp decline in density in diameter classes 2

and 3. *Lannea fruticosa* occurred at low density in diameter classes 1 and 2. *Boswellia papyrifera* was depicted in Bell-shape pattern, which reflects discontinuous or irregular recruitment. This species is one of the most economically important species for production of frankincense by local farmers and this factor accounts for low recruitment. *Sterculea setigera* followed a J-shape distribution pattern, reflecting severe limitation on regeneration (Peters 1996). This study noted that *Sterculea setigera* was one of the most important multipurpose tree species used mainly for fodder, especially during dry season when forage is scarce. *Pterocarpus lucens* also showed an Irregular-shape with complete absent from diameter classes 2 and 3. This also reflects limited regeneration, possibly due to human disturbance, livestock trampling or browsing, and other biotic and abiotic factors.

The cumulative height class distribution of all woody species followed an interrupted reverse J-shape pattern. According to Feyera et al. (2007), and Getachew and Abiyot (2006), a reverse-J-shape height class distribution pattern reflects a stable population. In this study, however, both the commutative and selected species analyses suggested a low regeneration profile. Accordingly, *Anogeissus leiocarpa* and *Combretum collinum* had an interrupted J-shape pattern while *Lannea fruticosa* had Bell-shape pattern. *Sterculea setigera* and *Pterocarpus lucens* followed an Irregular-shape while *Boswellia papyrifera* followed a J-shape pattern. This might be due to reasons given above with reference to diameter class distribution. Generally speaking, only *Anogeissus leiocarpa* and *Combretum collinum* were similar in both diameter class and height class distribution, showing an interrupted J-shape pattern. Otherwise, the other species showed that species differed in their density distribution patterns across height and diameter classes.

## Conclusions and recommendations

### Conclusions

Metema area has high diversity with even distribution of species, which included 42 herbs, 42 woody species, and 3 climbers. Few woody species occurred at high density or basal area. The patterns of cumulative diameter and height class frequency distribution of woody plants were in an interrupted inverted-J-shape, which reflected generally poor regeneration. Similarly, the population structures of the six selected important species reflected poor regeneration. *Sterculea setigera* showed least regeneration, followed by *Boswellia papyrifera* and *Pterocarpus lucens*.

### Recommendations

We offer the following recommendations:

Urgent research and/or development action is needed to stimulate regeneration by those species showing poor regeneration and high importance value indices: *Sterculea setigera*, *Boswellia papyrifera*, *Pterocarpus lucens*, *Boswellia pirottae*, *Tamarindus indica*, and *Terminalia laxiflora*

Research is needed on seed viability of the problematic spe-

cies, their seed raining mechanisms and problems, their seedling establishment mechanisms and problems, soil seed bank analysis and other ways to identify problems and remove threats to their regeneration.

Environmentally-friendly strategies are needed for effective scaling up of products and productivity of those economically important tree species such as *Boswellia papyrifera* and *Boswellia pirottae*. This will contribute to the conservation and development of other floral species in the area.

Finally, further research is needed to fill gaps of this research, especially related to investigation of socio-economic and ethnobotanical perspectives.

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**Appendix 1. List of plant species with their local name, botanical name, family, habit and author for Metema district**

Scientific Name	Local Name	FAMILY	Ha	Scientific Name	Local Name	FAMILY	Ha
<i>Acacia polyacantha</i> Willd.	Gimarda	Fabaceae	T	<i>Grewia bicolor</i> Juss.	Sefa	Tiliaceae	T
<i>Acacia seyal</i> Del.	Yebirchiko Girar	Fabaceae	T	<i>Hibiscus cannabinus</i> L.	Yebereha Bamia	Malvaceae	H
<i>Acacia sieberiana</i> Dc.	Nech Girar	Fabaceae	T	<i>Hygrophilia schulli</i> Almeida & Almeida	Amekella	Acanthaceae	H
<i>Acanthospermum hispidum</i> DC.	Akakima	Asteraceae	H	<i>Hyparrhenia arrhenobasis</i> (Hochst. ex Steud) Stapf	Wajel	Poaceae	H
<i>Achyranthes aspera</i> L.	Yeset Milas	Amaranthaceae	H	<i>Hypoestes forskalii</i> (Vahl.) R. Br	Ras Kimir	Acanthaceae	H
<i>Albizia lophantha</i> (Willd.) Benth	Sete Gimarda	Fabaceae	T	<i>Indigofera longibarbata</i> Engl.	Yeahiya Abish	Fabaceae	H
<i>Albizia melanoxylon</i> (A. Rich) Walp.	Gebso	Fabaceae	T	<i>Ipomoea aquatica</i> Forssk	Wuha Ankur	Convolvulaceae	H
<i>Allophylus rubiflorus</i> (A. Rich) Engl	Nechllo	Sapindaceae	H	<i>Ipomoea tenuirostris</i> Chisy	Hareg	Convolvulaceae	H
<i>Amaranthus hybridus</i> L.	Adis Mete	Amaranthaceae	H	<i>Lannea fruticosa</i> (Hochst. ex A. Rich) Engl	Digunguna	Anacardiaceae	T
<i>Anogeissus leiocarpa</i> (A. Rich) Guill. & Perr	Kirkira	Combretaceae	T	<i>Leucas martinicensis</i> (Jacq.) R. Br.	Awinda Mesay	Lamiaceae	H
<i>Aristida adoensis</i> Hochst	Gofer Sar	Poaceae	H	<i>Lonchocarpus laxiflorus</i> Guill. & Perr	Mebrat	Fabaceae	T
<i>Aristida hordeacea</i> Kunth	Jingira	Poaceae	H	<i>Maytenus senegalensis</i> Forssk	Dingay Seber	Celastraceae	Sst
<i>Asparagus Africanus</i> Lam.	Yeset Kest	Asparagaceae	Scs	<i>Maytenus undata</i> (Thunb.) Blakelock	Yebereha Atata	Celastraceae	S / T
<i>Balanites aegyptiaca</i> (L.) Del.	Lalo	Balanitaceae	T	<i>Melanthera abyssinica</i> (Sch.Bip. ex Rich.) Benth. & Hook. F.	Mech	Asteraceae	H
<i>Bidens pilosa</i> L.	Gurjejit	Asteraceae	H	<i>Monechma ciliatum</i> (Jacq.) Milne.Redh	Yeset Guticha	Acanthaceae	H
<i>Boerhavia erecta</i> L.	Aremo	Nycataginaceae	H	<i>Ochna leucophloeos</i> Hochst. ex A. Rich	Yedebene Fes	Ochnaceae	T
<i>Boscia mossambicensis</i> Klossch	Temenhie	Capparidaceae	S / T	<i>Ocimum urticifolium</i> Roth.	Yedimet Zinka Kibie	Lamiaceae	S
<i>Boswellia papyrifera</i> Hochst. ex Rich	Walya Meker	Burseraceae	T	<i>Oxytenanthera abyssinica</i> (A.Rich.) Mumro.	Shimel	Poaceae	H
<i>Boswellia pirottae</i> Choiv	Tikur Meker	Burseraceae	T	<i>Panicum monticola</i> Hook.f	Yekok Sar	Poaceae	H
<i>Bridelia micrantha</i> (Hochst.) Baill	Yenebir Tifir	Euphorbiaceae	S / T	<i>Pennisetum pedicellatum</i> Trin	Zemen Sar	Poaceae	H
<i>Calotropis procera</i> L.	Tobia	Asclepiadaceae	S	<i>Peristrophe paniculata</i> (Frossk) mit	Sire Bizu	Acanthaceae	H
<i>Celosia argentea</i> L.		Amaranthaceae	H	<i>Piliostigma thonningii</i> (Schumach.) Milne-Redth	Yekola Wanza	Fabaceae	T
<i>Cissus populnea</i> Guill. & Perr.	Azo Hareg	Vitaceae	C	<i>Polygala persicariifolia</i> DC.	Shetora	Polygalaceae	H
<i>Cobretum adenogonium</i> Steud.ex A.Rich	Tikur Abalo	Combretaceae	T	<i>Pterocarpus lucens</i> Guill. & Perr	Charia	Fabaceae	T
<i>Combretum collinum</i> Fresen	Askir	Combretaceae	T	<i>Satanocrater ruspolii</i> (Lindau) Lindau	Kesse	Acanthaceae	S
<i>Combretum hartmannianum</i> Schweinf	Teye	Combretaceae	T	<i>Senna occidentalis</i> (L.) Link	Yetezuari anit	Fabaceae	H
<i>Combretum molle</i> R. Br. ex G. Don	Nech Abalo	Combretaceae	T	<i>Setaria pumila</i> (Pair.) Roem & Schultt	Buanfie Sar	Poaceae	H
<i>Combretum sp</i> Fresen	Kongora	Combretaceae	T	<i>Sida urens</i> L.	Abelbalit	Malvaceae	H
<i>Commelina imberbis</i> Hassk	Wef Ankur	Commelinaceae	H	<i>Smithia abyssinica</i> (A. Rich.) Verdc	Chifrigina	Fabaceae	H
<i>Convolvulus Kilimandschari</i> Engl. & Diels	Abo Hareg	Convolvulaceae	H	<i>Snowdenia polystachya</i> (Fresen.) Pilg.	Dimamo	Poaceae	H
<i>Corchorus olitorius</i> L.	Kudra	Tiliaceae	H	<i>Solanum anguivi</i> Lam.	Embuay	Solanaceae	H
<i>Cyperus reduncus</i> Böck	Gicha	Cyperaceae	H	<i>Sterculea setigera</i> Del.	Darlie	Sterculiaceae	T
<i>Dalbergia melanoxylon</i> Guill. & Perr	Zobi	Fabaceae	S / T	<i>Stereospermum kunthianum</i> Cham	Zana	Bignoniaceae	S / T
<i>Desmodium dichotomum</i> (Klein. Ex Willd.) De	Gid Zemedede	Fabaceae	H	<i>Strychnos innocua</i> Del.	Kudkuda	Loganiaceae	S / T
<i>Dichrostachys cinerea</i> Wight & Am	Ader	Fabaceae	S / T	<i>Tamarindus indica</i> L.	Kummer	Fabaceae	T
<i>Dioscorea prahensis</i> Benth	Senssa	Dioscoreaceae	C	<i>Terminalia laxiflora</i> Engl. & Diels	Wembella	Combretaceae	T
<i>Diospyros abyssinica</i> (Hiem) F. Wite	Serkin	Ebenaceae	T	<i>Triumfetta annua</i> L.	Chegot	Tiliaceae	H
<i>Eragrostis macilenta</i> (A. Rich.) Steud	Yewef Sar	Poaceae	H	<i>Vigna ambacensi</i> Bak.	Yedur Barengua	Fabaceae	H
<i>Ethulia gracilis</i> Del.	Awunda	Asteraceae	H	<i>Ximenia Americana</i> L.	Enkoy	Olacaceae	S / T
<i>Euphorbia indica</i> Lam.	Wetet Awchi Kitel	Euphorbiaceae	H	<i>Zehneria scabra</i> (Linn. F.) Sond.	Hareg Eressa	Cucurbitaceae	H
<i>Ficus sycamoros</i> L.	Bamba	Moraceae	T	<i>Zinnia peruviana</i> (L.) L.	Yebereha Abeba	Asteraceae	H
<i>Ficus thonningii</i> Blume.	Chibha	Moraceae	T/S	<i>Ziziphus abyssinica</i> Hochst. ex A. Rich	Foch	Rhamnaceae	S / T
<i>Flueggea virosa</i> Guill. & Perr.	Shasha	Euphorbiaceae	T	<i>Ziziphus spina-christi</i> (L.) Desf.	Geba	Rhamnaceae	S/T
<i>Gardenia ternifolia</i> Schumach & Thonn	Gambilo	Rubiaceae	S/T				